Final Report
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Studies of the Nightside Ionospheres-Thermospheres of
Venus and Mars

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During the course of this grant, we studied the nightside ionosphere of Venus with a view toward obtaining information about the relative importance of plasma transport and particle precipitation in its maintenance.

We initially analyzed some of the PV re-entry orbits to determine what ion fluxes from the dayside or precipitating fluxes of electrons would be required to produce the measured densities. Although the conventional wisdom was that the nightside ionosphere is maintained by plasma transport during times of high solar activity and by electron precipitation at low solar activity, we found that the atomic ion densities indicate that, during the reentry period of moderately low solar activity as well, there is evidence for significant day-to-night plasma transport. A manuscript based on this study was published in December, 1993, (*Geophys. Res. Lett.*, *20*, 2739, 1993), and a copy is attached.

Using a combination of modeling and analysis of the Pioneer Venus data base, we constructed a map of the downward flux of O^+ over the nightside of Venus. We determined, via modeling, the nearly linear relationship between the downward flux of O^+ and the maximum density of O^+ as a function of solar zenith angle and local time. By comparing the predictions to models, we assigned a downward flux to each data point, and binned the data points as a function of local time and solar zenith angle. The maximum downward flux was seen at the terminators, and the fluxes were observed to fall off sharply toward the antisolar point. Weighting the average values for each bin, and assuming that the fluxes were a function of solar zenith angle alone, the average total downward ion flux over the nightside hemisphere was inferred. A value of 1.7×10^8 ions cm^{-2} s^{-1} was reported for the high solar activity nightside ionosphere, and the value inferred for the PV re-entry period was about a factor of 7 lower. A talk on "Nightward Fluxes of O^+ in the Venus Ionosphere", (J. F. Brannon and J. L. Fox), was presented at the Seventh Scientific Assembly of the International Association of Geomagnetism and Aeronomy, in Buenos Aires, August, 1993. A manuscript based on this work was published (*Icarus*, 112, 396-404, 1994) and a copy is attached.

A major effort during the grant period was the preparation of a chapter for the University of Arizona Press book *Venus II* entitled "Ionosphere: Solar Cycle Variations" (J. L. Fox and A. J. Kliore). A large portion of this chapter was devoted to describing what is known and unknown about the sources of the nightside ionosphere, and their solar cycle variations. A talk was presented at the conference *Venus II* in Tucson in January, 1995 on this subject, and the chapter has been

in press for the better part of a year. It will be published in about April, 1997. The chapter also contains some original calculations on the solar cycle variability of the Venus dayside ionosphere, which have not been published elsewhere up to this point. A copy of the page proofs is attached.

We originally had identified high mass-28 ion densities as the most important signature of electron precipitation in PV data of the Venus nightside ionosphere (J. L. Fox and H. S. Taylor, *Geophys. Res. Lett.*, *17*, 1625, 1990). In that study, we considered several Pioneer Venus orbits and attempted to identify the "auroral" and "non-auroral" orbits. Since then, an instrumental error in the PV OIMS has rendered the very high ($\sim 10^4\,cm^{-3}$) mass-28 ion densities suspect. We have partially analyzed this effect, and a talk entitled "Anomalous mass-28 ion densities in the Venus nightside ionosphere" (J. L. Fox, J. F. Brannon, J. Grebowsky, and H. S. Porter) was presented at the 1994 Spring Meeting of the American Geophysical Union, Baltimore, May, 1994. Work on this subject was interrupted by the sudden termination of support for the VDAP program.

We also began a study of the chemistry of the Venus nightside auroral ionosphere (as opposed to the nightside ionosphere produced by transport of plasma). We have found that the ion density peaks produced by precipitating electrons with sufficient fluxes to reproduce the measured O^+ peak densities are not indicative of photochemical equilibrium, and the densities profiles are influenced by diffusion also. The boundary of the photochemical equilibrium region is very low. We investigated the sources and sinks of various ions, in order to compare them to those for the transport dominated ionosphere. A talk entitled "Chemistry of the auroral Venus nightside ionosphere" (J. F. Brannon, J. L. Fox, and H. S. Porter), was presented at the 30th Scientific Assembly of COSPAR, Hamburg, Germany, July, 1994. We were in the process of preparing a manuscript on the chemistry of the auroral Venus ionosphere, but this work was also interrupted because of the sudden termination of funding for the VDAP program.

This grant also partially supported the preparation of a chapter entitled "Aeronomy" for the *Atomic, Molecular and Optical Physics Handbook*, edited by G. W. F. Drake, American Institute of Physics Press, Woodbury, NY, 1996, pp. 940–968.